A Summary: The 7th US Climate Modeling Summit (USCMS) and Workshop (28 June – 01 July 2021)

Presentation to the USGCRP SGCR on 15 September 2021

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NCAR

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Background on USCMS and Workshop

The USGCRP's IGIM has been convening an annual USCMS since 2015 to improve the coordination and communication of national climate modeling goals and objectives. These objectives include:

- Developing a shared understanding of modeling groups' directions and implementation strategies;
- Identifying opportunities for enhanced coordination and synergy among modeling groups; and
- Identifying outreach opportunities to user communities.

The Summits bring together representatives from the US climate model development centers and from operational climate and weather prediction programs:

- Geophysical Fluid Dynamics Laboratory (GFDL CM/ESM);
- Goddard Institute for Space Studies (GISS ModelE);
- Global Modeling and Assimilation Office (GMAO GEOS);
- NCAR Community Earth System Model (CESM);
- NWS/NCEP (GFS); and
- DOE Energy Exascale Earth System Model (E3SM).

Background on USCMSs and Workshops

Starting in 2017, a topical workshop has also been organized under the auspices of the USCMS and in conjunction with the annual meeting.

These workshops serve as a venue to have focused technical communications on a high-priority modeling-related topic identified by the modeling centers together with the IGIM, and they include invitees from the broader community.

USCMS Meeting Agenda

Part I: Workshop summary and updates from activities that started at previous USCMS meetings

Part II: Updates from the centers

Part III: Discussion on topics of interest

Summary of Projects Initiated at the Previous USCMSs

The *world-avoided* mini-Model Intercomparison Project (mini-MIP), lead Jean-Francois Lamarque (NCAR):

It aims to look at the impacts that the Clean Air Acts have had on air quality and climate, by developing appropriate emission scenarios.

An initial set of simulations have been performed by CESM2 (WACCM), DOE (E3SM), NASA GISS (modelE), and NOAA GFDL (ESM4).

The results show significant impacts of US emission trajectories on global surface ozone concentrations and particulate pollutions.

Next steps involve more analysis of the simulations focusing on impacts on climate, air pollution, and health with expected completion of the project within the next year.

Summary of Projects Initiated at the Previous USCMSs

Examining the Physical Realism of Aerosol-Induced Cloud Drying Across US Models, leads Johannes Mülmenstädt (PNNL) and Susanne Bauer (NASA GISS):

The Project emerged from last year's USCMS Workshop on Aerosol – Cloud Interactions.

All six modeling centers are participating in this project that combines observational data with model results and theoretical studies to better understand the physical realism of aerosol-induced cloud drying across models.

The research plan includes the following steps:

1. Evaluation of the relationships between cloud droplet number concentrations and liquid water path;
2. Investigation of physical realism of the entrainment fluxes in models;
3. Testing process interpretation of satellite correlations; and
4. Linking entrainment mediated aerosol – cloud interactions with cloud feedbacks.

The project is anticipated to be completed within a one-year time frame.

Updates from Centers

In the second segment, the six modeling centers provided updates on their science, priorities, challenges, and plans.

These presentations generally covered the centers' new model configurations, developments, frameworks, initiatives, and some results of interest, including those from CMIP6 simulations.

Discussion Topics

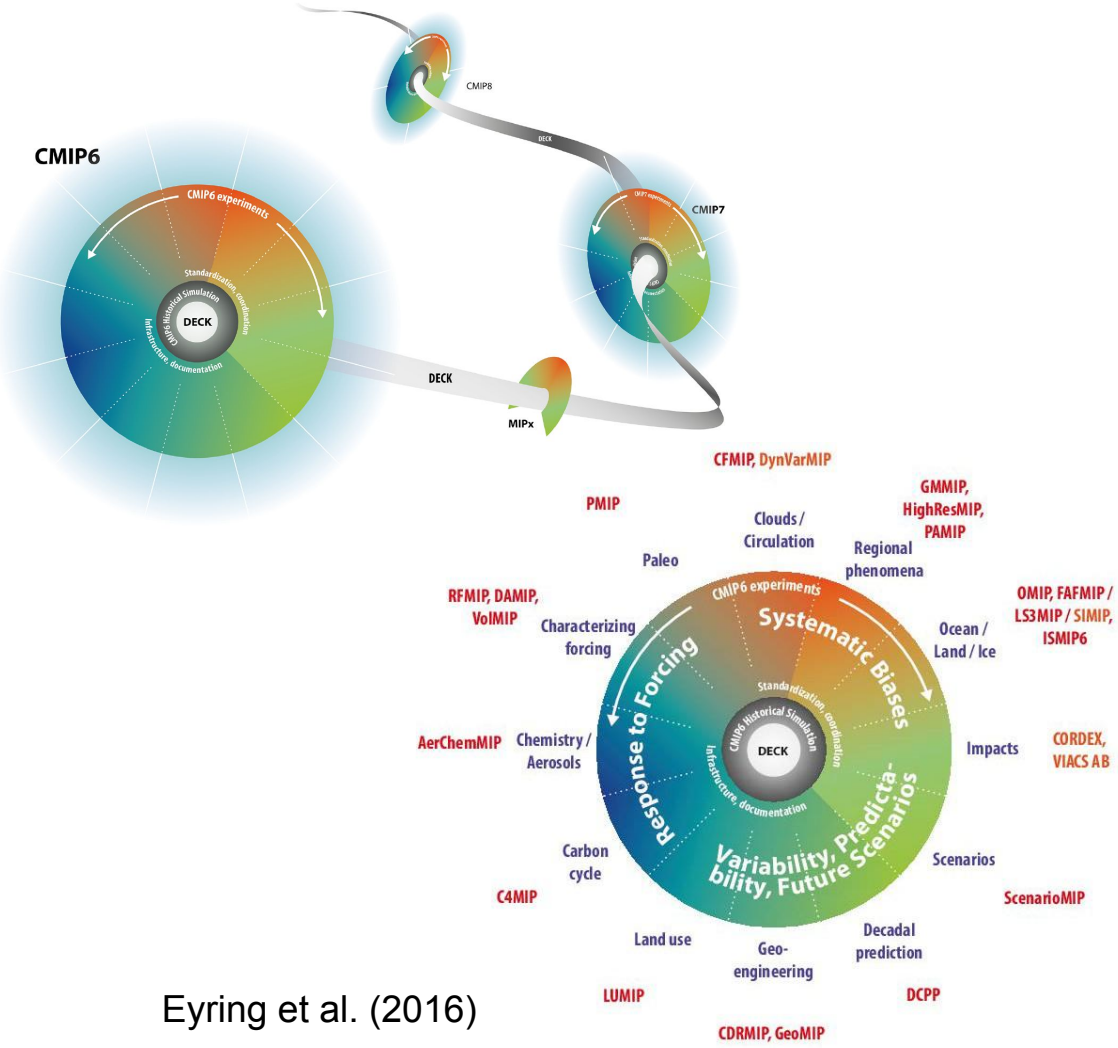
Future of the Coupled Model Intercomparison Project (CMIP) and the US centers' participation in related activities:

CMIP6, with its many MIPs, was an enormous undertaking, generating 9 PB of data globally and significantly straining US modeling centers' human and computational resources.

Despite its challenges, CMIP6 enabled meaningful collaborations globally between modeling centers and many research institutions.

CMIP6 certainly resulted in new science and findings, particularly via its MIPs. Relatedly, the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report was published in August 2021.

Four US modeling centers participated heavily in CMIP6, i.e., DOE/E3SM, NASA/GISS, NOAA/GFDL, and NSF/CESM, and feature strongly in the overall report.



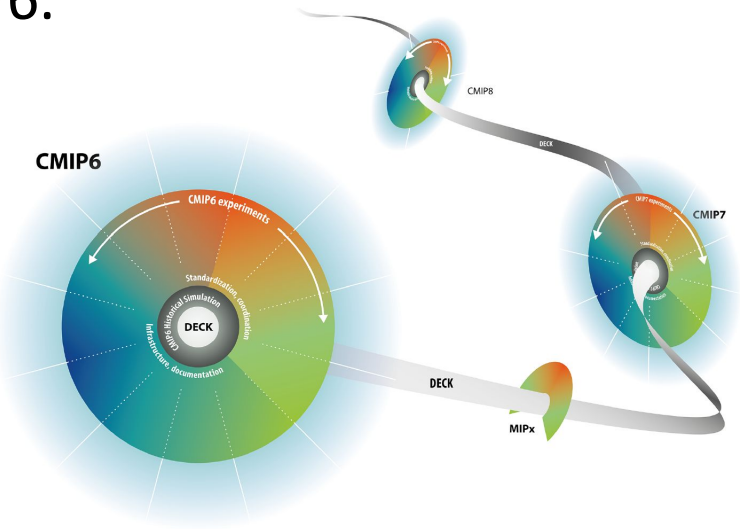
Eyring et al. (2016)

Discussion Topics

Future of the Coupled Model Intercomparison Project (CMIP) and the US centers' participation in related activities:

While plans for the future of CMIP are still under discussion, the US modeling centers strongly favor a more continuous approach where model simulations can be contributed to repositories as they become available on the centers' own development and science timelines.

Such a continuous approach was also the intention in CMIP6.



Discussion Topics

Opportunities Arising from the Administration's Focus on Climate Science:

Climate-related research with renewed focus on topics such as basic research, modeling, projections, and Earth system predictions.

Specific emphasis areas include, e.g., climate actions and solutions, adaptations, preparedness for extreme events, noting also that climate solutions include growing interest areas of clean energy, climate policy, cost of carbon, and financial and human risks.

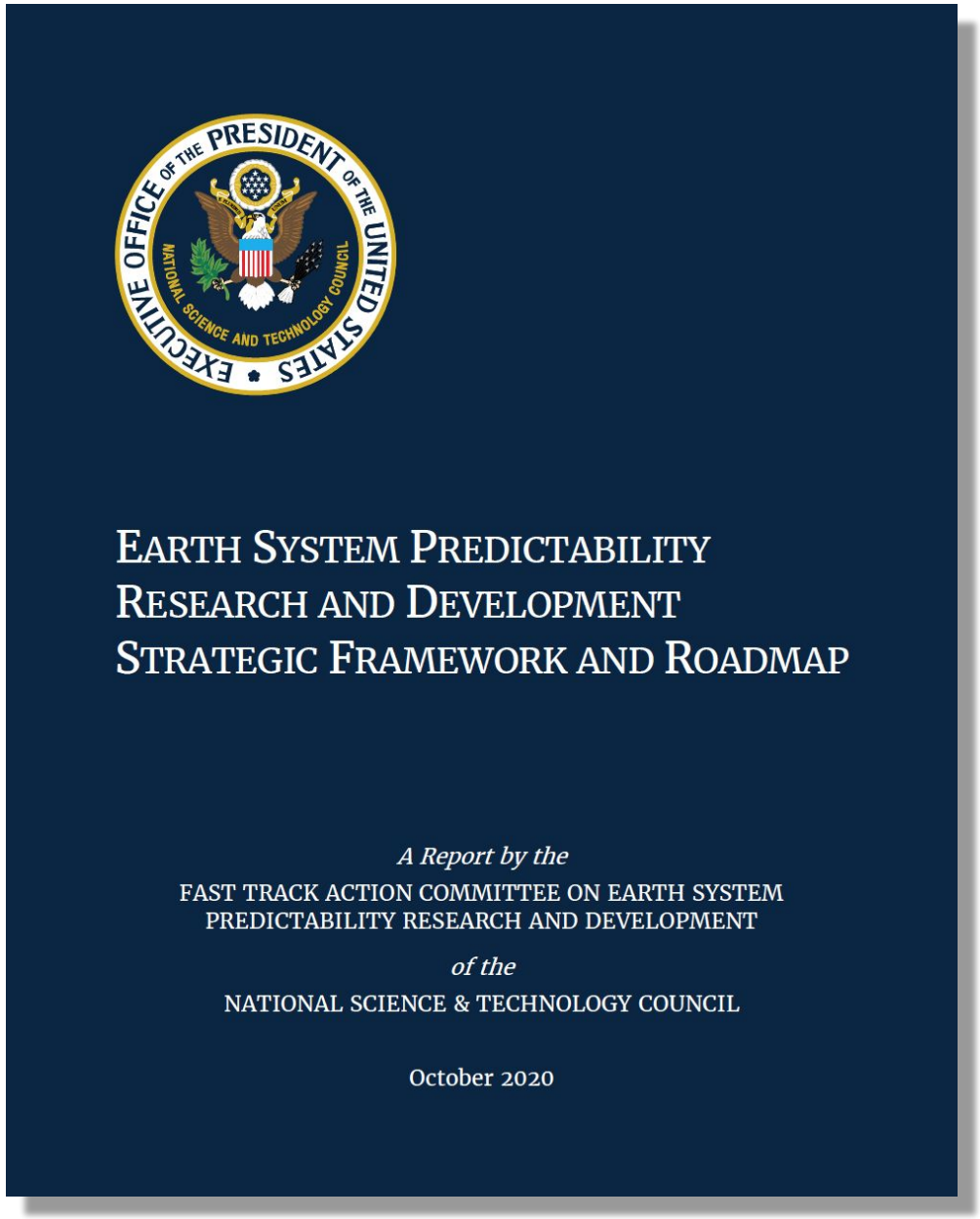
These areas would enable more interdisciplinary research.

A new emerging topic is *environmental justice*. Related research would tackle, among others, what relevant and actionable information models can provide.

Climate research must be translated into more innovative solutions, integrating climate science with information needed by stakeholders.

A Summary: The USCMS Topical Workshop on *Predictability Limits Arising from Model and Prediction System Challenges (28-30 June 2021)*

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.



Topic: Predictability

Goal 3: Accelerate the exploration and effective use of inherent Earth system predictability through advanced modeling.

Objectives:

1. Integrate new observations, process understanding and emerging technologies to reduce model biases.
2. Develop a modeling framework that leverages U.S. efforts to enable extensive exploration of ESP, including high-resolution, integrated, multiscale/seamless Earth system modeling tools.
3. Develop and apply advanced methodologies of model-data assimilation[15] to improve the use of inherent predictability.
4. Use models in targeted experiments and diagnostics to improve model fidelity and probe predictability frontiers including large ensembles, high-resolution experiments and advanced model benchmarking, diagnostics, visualization, and data analytics methodologies.
5. Expand, share, and broaden community access to computing infrastructure for model-data integration, model comparisons, and model exploration of predictability.

Area of Opportunity #5: Advanced Modeling and Technology, and Enhanced Collaborations

- Integrate ML / AI in modeling
- Reduce model errors
- Explore signal-to-noise ratio with large ensembles
- Increasingly integrate biosphere and human systems in ESMs
- Explore the impact of resolving clouds and ocean eddies in ESMs
- Enhance computational infrastructure and efficiency for extensive modeling explorations
- Coupled ESM data assimilation to harness predictability
- Enhancing coordination and collaboration for Earth system modeling to understand and harness predictability

The specific Workshop topics that are naturally inter-related are:

- Impacts of model errors (biases) and resolution on predictability, including air-sea and aerosol-cloud interactions that can limit predictability
- Signal-to-noise ratio (paradox) and role of large ensembles

Emphasis areas included impacts of these issues / challenges on predictability of extreme events such as heat waves, precipitation, droughts, etc.

The time scales of interest extend from weather and subseasonal to decadal and longer.

USCMS Topical (virtual) Workshop on

Predictability Limits Arising from Model and Prediction System Challenges

28-30 June 2021
(All times are EDT)

(version 24 June 2021)

28 June 2021 (Monday)

Chair: Gokhan Danabasoglu

11:00 Gary Geernaert: Welcome and Background

11:10 Gokhan Danabasoglu: Workshop objectives and outcomes

11:20 Annarita Mariotti: Earth system predictability R&D interagency strategy and roadmap

11:45 Jim Hurrell: Summary and outcomes of the NAS meeting on predictability

Modeling Center Efforts

12:10 Baoqiang Xiang: "Seamless system for Prediction and EArth system Research" (SPEAR) S2S prediction system and its prediction of different types of MJO

12:35 Feiyu Lu: Relating predictability, predictions, and model bias for seasonal predictions with GFDL's "Seamless system for Prediction and EArth system Research" (SPEAR)

13:00 *Break*

Chair: Susanne Bauer

13:25 Yaga Richter: Subseasonal prediction research framework with CESM2 and examples of its use for understanding sources of predictability

13:50 Steve Yeager: The benefits of large ensembles in CESM multiyear to decadal predictions

14:15 Ruby Leung: Overview of DOE activities

14:40 Jerry Meehl: Initialization method and model bias, drift, trends, and skill of seasonal-to-decadal initialized climate predictions in CESM and E3SM

15:05 Gokhan Danabasoglu: Charge for breakout groups and anticipated outcomes

15:30 *Adjourn for the day*

29 June 2021 (Tuesday)

Chair: John Dunne

Modeling Center Efforts (continued)

11:00 Avichal Mehra: Development of GEFS/SFS models

11:25 Vijay Tallapragada: Development of coupled UFS for medium range and S2S predictions: A collaborative effort supported by the UFS-R2O project

11:50 Clara Orbe and Ron Miller: Overview of predictability using the GISS model

Air-Sea Interactions; Signal-to-Noise Paradox; Model Deficiencies

12:15 Doug Smith: A signal-to-noise paradox in climate science

12:40 Chris Roberts: Role of resolution and SST biases in predictability in the ECMWF model

13:05 *Break*

Chair: Maria Molina

13:30 Ben Kirtman: Sub-seasonal to decadal predictability and prediction with ocean eddy resolving models

13:55 Isla Simpson: Model deficiencies in the representation of low frequency variability and/or forced trends

14:20 Breakout Groups (5-10 groups)

15:30 *Adjourn for the day*

30 June 2021 (Wednesday)

Chair: Haiyan Teng

Focus Areas

11:00 Susannah Burrows: Predictability limits due to aerosol – Earth system interactions

11:25 Maria Molina: Overcoming and detecting model predictability limits using machine learning

11:50 Yuejian Zhu: Stochastic forcing, ensemble development, and reanalysis and reforecast

12:15 Ming Zhao: Simulations of atmospheric rivers, their variability, and response to global warming using GFDL's new high-resolution general circulation model

12:40 Wenhao Dong: Projected changes in monsoon low pressure/depression systems and precipitation patterns

13:05 *Break*

Chair: Gokhan Danabasoglu

13:30 Celine Bonfils: Disentangling the role of aerosols and greenhouse gases in the recent decadal changes in hydroclimate

13:55 Haiyan Teng: Heat waves and the 1990s shift

14:20 Summaries from Breakout Groups

14:45 Discussion

15:30 *End of the Workshop*

Expected Outcomes

- Exchange of information
- One or two specific studies that can be undertaken by the modelling centers collaboratively, primarily using existing simulations to address identified topic(s).
- The timeline of the project would be ~1 year.
- A product would be one or two collaborative publications.

Registrants: ~85

Attendance: 40+ to ~70

Jun. 28–30, 2021

9:00am-1:30pm MT (11:00am-3:30 ET)

VIRTUAL WORKSHOP

REGISTER HERE

To improve the coordination and communication of national (US) climate modeling goals and objectives, USGCRP's Interagency Group on Integrative Modeling (IGIM) convenes US Climate Modeling Summit (USCMS) meetings annually. Each USCMS is accompanied by a workshop that is timely and of interest to the centers and also could lead to new collaborative and coordinated activities. This year's workshop will be on "Predictability Limits Arising from Model and Prediction System Challenges". It will be held virtually over the three-day period 28-30 June 2021 between 11:00 – 15:30 EDT on the Zoom platform and the meeting links will be sent to registered participants.

The specific Workshop topics that are naturally inter-related are:

- Impacts of model errors (biases) and resolution on predictability, including air-sea and aerosol-cloud interactions that can limit predictability
- Signal-to-noise ratio (paradox) and role of large ensembles

A major emphasis will be on impacts of these issues / challenges on predictability of extreme events such as heat waves, precipitation, droughts, etc., but also of hurricanes, atmospheric rivers, etc. The time scales of interest can extend from weather and subseasonal to decadal and longer time scales.

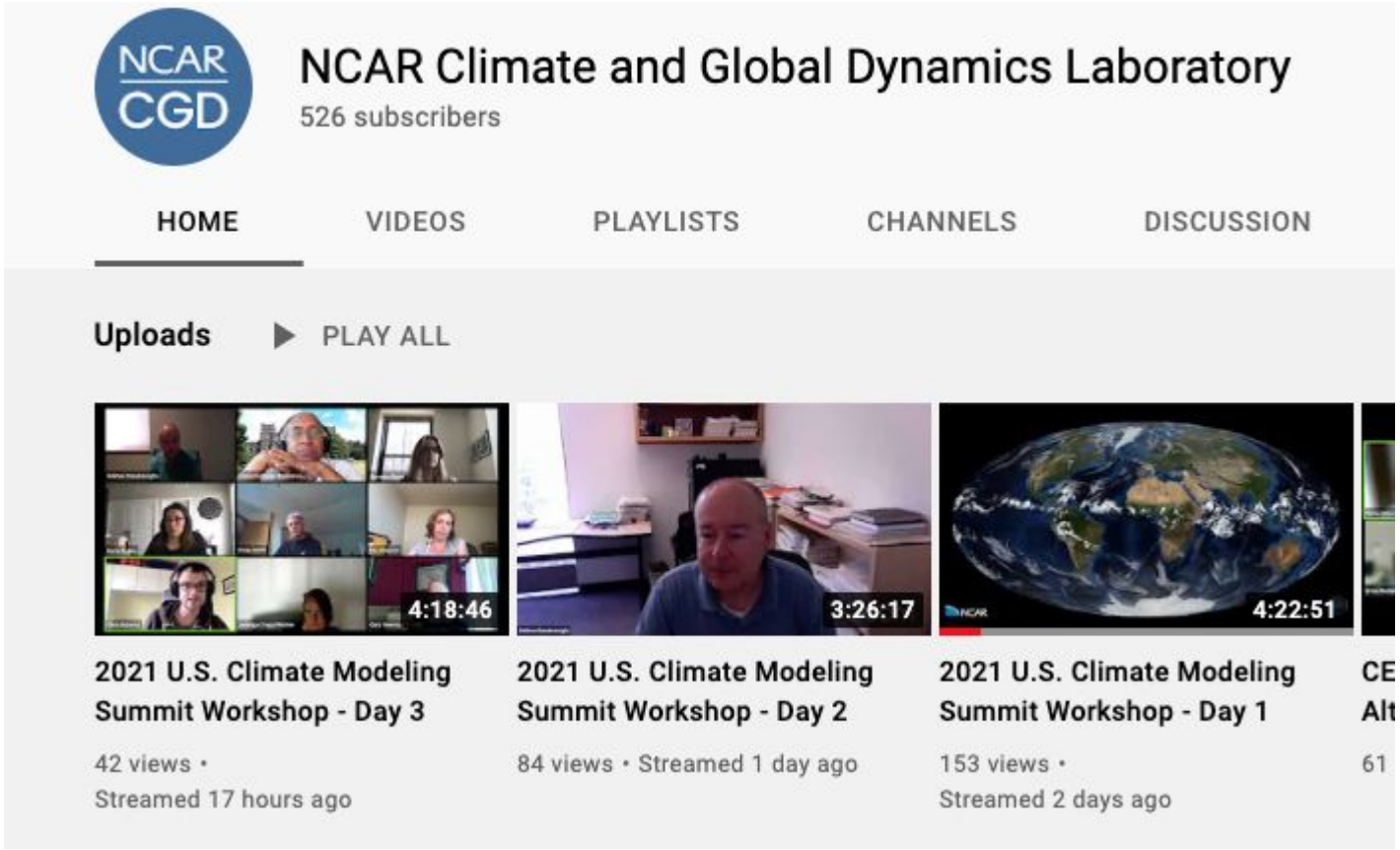
The expected Workshop outcomes include:

- Identification of coordinated experiments and / or analysis that would complement existing CMIP5 / 6 simulations and large ensembles (both initialized and uninitialized)
- One such effort could be studying (limits on) predictability of extreme events that arise from model fidelity issues. This study would make use of many existing simulations as well as the analog method.

Workshop Details

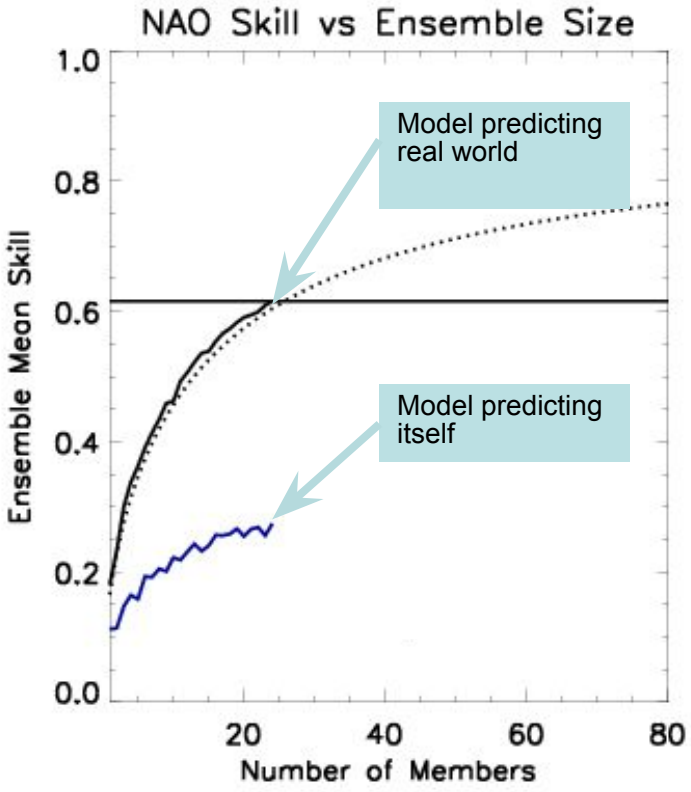
- **Dates**: 28 - 30 June 2021
  - Add to Google calendar
  - Add to Outlook Calendar
  - Add to Office 365 Calendar
  - Add to Yahoo Calendar
  - Download ICS file
- **Location**: Virtual Workshop Via Zoom & NCAR CGD Youtube
- **Contact**: Todd Amodeo [amodeo@ucar.edu]
- **Agenda**: PDF
- **Registration**: Register Here

https://www.cesm.ucar.edu/events/2021/uscms/



Charge for Breakout Groups

- How can we demonstrate aspects of the impacts of model biases and resolution on limiting predictability?
- Relatedly, what are the limits on predictability of, say, extreme events that arise from model fidelity issues?
- How can we make meaningful contributions to furthering our understanding of the signal-to-noise ratio (paradox)?
- What is the role of initialized and uninitialized large ensembles in these efforts?



From Doug Smith (UK Met Office)

Formulation of a project is in the works!

The Next Steps …..

Two proposal ideas:

- Does improved representation of modes of variability lead to reduced biases and increased prediction skill in US climate models?
- How much do persistent model biases impact prediction skill?

Environmental justice

Does Improved Representation of Modes of Variability Lead to Reduced Biases and Increased Prediction Skill in US Climate Models?

Representation of Modes of Variability in Six U.S. Climate Models

CLARA ORBE,[a] LUKE VAN ROEKEL,[b] ÁNGEL F. ADAMES,[c] AMIN DEZFULI,[d,e] JOHN FASULLO,[f] PETER J. GLECKLER,[g] JIWOO LEE,[g] WEI LI,[h] LARISSA NAZARENKO,[i,a] GAVIN A. SCHMIDT,[a] KENNETH R. SPERBER,[g] AND MING ZHAO[j]

[a] *NASA Goddard Institute for Space Studies, New York, New York*
[b] *T-3 Solid Mechanics and Fluid Dynamics, Los Alamos National Laboratory, Los Alamos, New Mexico*
[c] *University of Michigan, Ann Arbor, Michigan*
[d] *Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, Maryland*
[e] *Science Systems and Applications, Inc., Lanham, Maryland*
[f] *National Center for Atmospheric Research, Boulder, Colorado*
[g] *Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory, Livermore, California*
[h] *IMSG at Environmental Modeling Center, NOAA/National Centers for Environmental Prediction/National Weather Service, College Park, Maryland*
[i] *CCSR, Columbia University, New York, New York*
[j] *Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey*

Finally, while the results from our analysis suggests a clear progression in model fidelity in a climate context, it is not clear how (if) this improved performance translates to skill in subseasonal forecasting. Our limited analysis comparing two subseasonal forecast groups suggests that the factors contributing to improved QBO performance in the climate context may also improve skill on subseasonal time scales. However, owing to the limited number of subseasonal models considered in this study, our analysis is not conclusive. As more forecast systems become available in parallel with new CMIP6 models, however, it will become easier to address this question.

Does Improved Representation of Modes of Variability Lead to Reduced Biases and Increased Prediction Skill in US Climate Models?

Focus on the representation of the MJO for the subseasonal-to-seasonal and the NAO for the interannual-to-decadal time scale predictions to entrain participation of centers.

Based on various metrics, evaluate how the representations of modes are related to relevant model biases, e.g., precipitation in the western Pacific and the northern North Atlantic surface temperatures, respectively.

Evaluate and document if improved modes of variability and / or reduced bias translate into improved predictions, perhaps focusing on a few events.

Evaluate relationships between modes of variability and extremes.

Investigate any changes in S2N ratio.

Does Improved Representation of Modes of Variability Lead to Reduced Biases and Increased Prediction Skill in US Climate Models?

Period of performance: ~1 year

Funding level: ~1 FTE, but primarily at a single institution

Although this topic emerged from the Workshop discussions, we need get the buy-in from the modeling centers and modify as necessary to accommodate centers' interests

How Much do Persistent Model Biases Impact Prediction Skill?

This is an important question that keeps coming up continuously.

There is some evidence that bias reductions may lead to better prediction skills.

The idea here is to use artificial bias correction techniques and perform subseasonal-to-decadal prediction experiments, and then compare skill to those from their existing prediction simulations.

This project will require a higher level of (personnel and computational) commitments from the centers.

Period of performance: 2+ years

Funding level: Maybe several FTEs distributed across centers

Perhaps only a few of the centers may participate

Environmental Justice

What can USCMS can deliver as a modeling community towards addressing new questions and challenges?

It was agreed upon to focus work on environmental justice.

Next steps would be to agree on action items to start and expand this discussion.

There was the idea to have an additional meeting within this group to discuss or to have it as part of the IGIM meeting agenda, including invited talks about environmental justice.

Thank You!